MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2017/2018

ENT3076 – NANO-SCIENCE

(NANO)

5 MARCH 2018
9:00 a.m – 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 5 pages with 4 Questions only.
2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

Table Q1 lists the basic parameters of Gallium Arsenide (GaAs), Gallium Nitride (GaN), Gallium Phosphide (GaP), Indium Phosphide (InP), Aluminum Arsenide (AlAs) and Aluminum Nitride (AlN).

Table Q1

Material	Electron Affinity	Energy Bandgap	Electron Effective Mass	Hole Effective Mass	Lattice Constant
GaAs	4.07eV	1.42eV	0.063 m_o	0.51 m_o	5.65Å
GaN	4.10eV	3.20eV	0.20 m_o	0.82 m_o	4.52Å
GaP	3.80eV	2.26eV	0.79 m_o	0.83 m_o	5.45Å
InP	4.38eV	1.34eV	0.08 m_o	0.60 m_o	5.87Å
$Al_{0.1}Ga_{0.9}As$	3.96eV	1.55eV	0.07 m_o	0.54 m_o	5.65Å
$Al_{0.8}Ga_{0.2}As$	3.53eV	2.09eV	0.13 m_o	0.71 m_o	5.66Å
AlN	0.60eV	6.03eV	0.40 m_o	7.20 m_o	3.11Å

(a) According to Table Q1, list the materials that can form Type-I heterostructure with GaAs. Justify your answer. [4 marks]

(b) A quantum well is formed by GaAs and $Al_{0.1}Ga_{0.9}As$ and has **ONLY 1** subband level for both electrons and holes confinement.

(i) What is the thickness of quantum well if the subband energy for electrons confinement is 0.05eV? [4 marks]

(ii) Calculate the subband energy for holes confinement. [4 marks]

(iii) Determine the emitted wavelength of the light emitting diodes that fabricated by using this quantum well. [4 marks]

(iv) Calculate the density of sate per unit area for electrons if the total energy of electron gas in the quantum well is 0.07eV. [4 marks]

(c) If the structure in Question 1(b) is fabricated layer-by-layer for few times, what structure will be formed? Explain this structure with the aid of a diagram. [5 marks]

Question 2

(a) $Al_{0.1}Ga_{0.9}As$ and $Al_{0.8}Ga_{0.2}As$ have different fractions in Al and Ga. Hence, they are different in energy bandgap and properties. Explain the different properties between $Al_{0.1}Ga_{0.9}As$ and $Al_{0.8}Ga_{0.2}As$ with the transition of energy bandgap. [8 marks]

(b) (i) Draw the energy band diagram for InP/GaAs/InP quantum heterostructure and label the electron affinity, energy bandgap, $|\Delta E_c|$ and $|\Delta E_v|$ in the diagram. [8 marks]

Continued ...

(b) (ii) Calculate the $|\Delta E_c|$ and $|\Delta E_v|$ for InP/GaAs/InP quantum heterostructure. [2 marks]

(iii) Identify InP/GaAs/InP quantum heterostructure is either Type-I (straddling), Type-II (staggered) or Type-II (broken gap). Justify your answer. [3 marks]

(c) With the aid of a diagram, briefly explain misfit dislocation and threading dislocation in semiconductor heterostructures. [4 marks]

Question 3

(a) (i) Electrons in a bulk material are defined based on the electron temperature. Give the definitions of different electron temperature with respect to the crystal temperature and briefly explain it. [3 marks]

(ii) With the aid of diagrams, briefly explain the miniaturization effects on hot electrons. [8 marks]

(iii) Explain how transient overshoot effects can be applied in high speed and high frequency devices [5 marks]

(b) What is the device that shown in Figure Q3(b)? With the aid of diagrams, explain how negative differential resistance occurs in current-voltage charasteristics of this device. [9 marks]

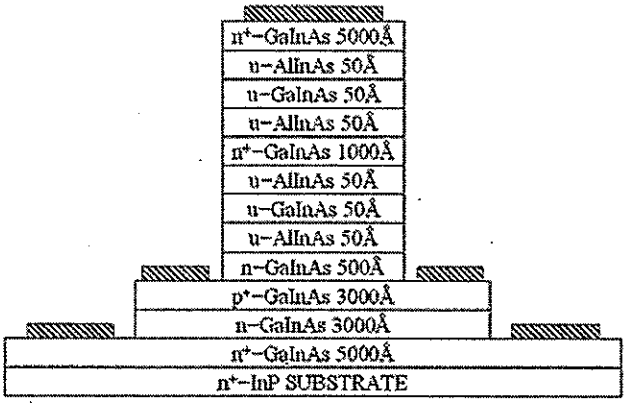

Figure Q3(b)

Question 4

(a) Define ballistic-injection devices and explain the electrons transport in the devices. [7 marks]

(b) (i) What are the TWO processes of intraband transition of electron in a quantum well? [2 marks]

Continued ...

(ii) A red shift on the absorption coefficient of quantum well is observed when electric field is applied perpendicular to the quantum well. What is this phenomenon? With the aid of a band diagram, briefly explain why this phenomenon occurs. [6 marks]

(iii) Electron-hole plasma is excited when a laser pulse incident on a material. However, electron-hole plasma cannot maintain excited due to relaxation. With the aid of diagrams, briefly explain all the stages in the relaxation of photoexcited electron-hole plasma. [10 marks]

End of Paper.